WATER CHEMISTRY ANALYSIS IN RSG-GAS SECONDARY COOLING SYSTEM

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ABSTRACT

WATER CHEMISTRY ANALYSIS IN RSG-GAS SECONDARY COOLING SYSTEM. The G.A Siwabessy reactor (RSG-GAS) located in the Puspiptek area uses water as a coolant. The water as a coolant will contact directly with the component or structure of the reactor, that a chemical reaction between water and those components might cause the possibility of corrosion process. Therefore, cooling water quality will determine the integrity of reactor components or structures. The research described in this paper was conducted in order to monitor the quality of secondary cooling water, so that the water quality specifications is maintained and the reactor can be safely operated. One way to monitor the cooling water quality is by performing analysis into the secondary cooling water and raw water on June 6, 2016. The methodology used was by analysing the pH value using a pH-meter, conductivity value using Conductivity-meter, water hardness analysis, and analysis for some chemical elements such as Cl-, SO_4^{2-}, Fe, P using calibrated Spectrophotometer DR / 2400. Corrosion rate of the carbon-steel as the piping material of secondary cooling system under environmental corrosion condition was also analyzed using the Potentiostat. From those performed analysis, the overall measured values are still below the standard values as required in the RSG-GAS safety analysis report document, meaning that the water quality management of the secondary cooling system has been well performed so far.

Keywords: analysis, water chemistry, secondary cooling, RSG-GAS

ABSTRAK

ANALISIS KIMIA AIR PADA SISTEM PENDINGIN SEKUNDER RSG GAS. *Reaktor Serba Guna G.A Siwabessy (RSG-GAS) yang terletak di kawasan Puspiptek, menggunakan air sebagai pendingin. Air sebagai pendingin akan berhubungan langsung dengan komponen atau struktur reaktor, sehingga reaksi kimia antara air dan komponen akan menimbulkan kemungkinan terjadinya korosi. Oleh karenanya, kualitas air pendingin akan mempengaruhi integritas komponen atau struktur reaktor. Penelitian dalam makalah ini dilakukan dengan tujuan untuk memantau kualitas air pendingin sekunder RSG-GAS sehingga spesifikasi kualitas air pendingin tetap terjaga dan reaktor akan beroperasi dengan aman. Salah satu cara pemantauan terhadap kualitas air pendingin diantaranya adalah melalui analisis air pendingin sekunder dan analisis raw water pada tanggal 22 Juni 2016. Metodologi dari penelitian ini adalah dengan cara analisis pH dengan menggunakan pH meter, analisis konduktivitas air menggunakan Conductivity-meter, analisis kesadahan air, dan analisis beberapa kandungan unsur kimia seperti* Cl^-, SO_4^{2-}, *Fe, P dengan alat spektrophotometer DR/2400 yang sudah terkalibrasi. Selain itu juga dilakukan analisis laju korosi dengan menggunakan alat potensiostat pada baja karbon sebagai material pipa pendingin sekunder dalam lingkungan air pendingin yang rawan korosi. Hasil beberapa analisis di atas menunjukkan nilai-nilai terukur secara keseluruhan masih di bawah nilai standar seperti yang dipersyaratkan dalam dokumen Laporan Analisis Keselamatan (LAK) RSG-GAS, yang berarti bahwa pengelolaan terhadap kualitas air pendingin sekunder sejauh ini sudah dilakukan dengan baik.*

Kata kunci*: analisis, kimia air, pendingin sekunder, RSG-GAS*

INTRODUCTION

The secondary cooling system of the RSG-GAS reactor serves to transfer heat from the primary cooling system into the environment through cooling chimney. It is an open type of recirculating systems, which means that the air will directly contact the cooling system components. There are several problems that may arise in the open recirculating cooling water systems including the growth of microorganisms. The presence of these microorganisms will lead the mucus from secretion of microorganisms [1-4]. This mucus will bind the solids suspended and accumulated at the intersection in the pipeline, so that they will reduce the water flow in the cooling system and decrease the efficiency of the heat exchanger. Microorganisms will also disrupt the cooling system and accelerate the corrosion process [5,6]. The RSG-GAS secondary coolant, which has an open recirculation system, will be susceptible with microbes entering into the system, so that there is some oxidation reaction in the pipeline system and cause corrosion process [7- 9]. Therefore, monitoring of the water chemistry in the secondary cooling system is needed. Control of chemical water quality in the secondary cooling system can be performed by using chemicals additive added into the secondary cooling system [10,11]. The cooling water quality will affect with the integrity of reactor components, because water might be aggressive to the metal components of the reactor coolant system. Therefore, the water used as a coolant must meet the requirements according to the reactor components. Monitoring on the reactor cooling water quality is needed to reduce the problems arising due to the the cooling water, like corrosion, crust and growth of moss or microorganisms. The research described in this paper was conducted in order to monitor the quality of secondary cooling water, so that the water quality specifications are maintained and the reactor can be safely operated. One way to monitor the cooling water quality is by performing analysis into the secondary cooling water and raw water, which were conducted in 2016. Raw water is the water coming from the Puspiptek pipeline, and secondary cooling water is the raw water already given some additives to be used in the RSG GAS secondary cooling system. The methodology used was by analysing the pH value using a pH-meter, conductivity value using conductivity-meter, water hardness analysis, and analysis for some chemical elements such as Cl-, SO_4^{2-}, Fe, P using calibrated spectrophotometer DR / 2400. Corrosion rate of the carbon-steel as the piping material in the secondary cooling system under environmental corrosion condition was also analyzed using the potentiostat.

THEORY

Monitoring of the secondary cooling water quality is aimed to maintain the water quality under required safety standard. It can reduce some problems that may arise in the secondary cooling system such as corrosion, scale, microorganisms and moss. The method is measurements of pH, conductivity, and the trace elements such as Ca, SO_4, Cl, Fe, water hardness, and the corrosion rate. The pH is an important parameter for determining the levels of acid or base in a solution. Determining pH is very important in maintaining the quality of water chemistry. The pH is used to determine the alkalinity, CO_2 and acid-base equilibrium. The intensity of the acidic or basic character of a solution is indicated by pH and hydrogen ion activity. A normal pH value is 7, if the value of pH > 7 the solution has alkaline properties and if the value of pH < 7 the solution is acidic. Conductivity water analysis is also very important to be performed, because the conductivity is the ability of a solution to conduct electricity and to predict the water hardness in the water. The more dissolved salts which can be ionized, the greater is the conductivity value. Measurements are carried out based on the ability of cations and anions to deliver electrical current. If the electrical conductivity value is big, then the ability of cations and anions to conduct the electric current is also big.

METHODOLOGY

Monitoring the water chemistry is achieved by several ways. Trace elements are measured using spectrophotometer, while other parameter such as pH and water conductivity are measured using a pH-meter conductivity-meter. This section will describe oly the procedures of using spectrophotometer and analysis of corrosion rate.

Water chemistry analysis using a spectrophotometer

Analysis of water chemistry on the RSG -GAS secondary cooling system has been carried out in the chemical laboratorium of PRSG using the spectrophotometer DR / 2400 HACH brand. The trace elements measured using this tool include Fe, SO_4^{2-}, Silica HR, P, reactive Cl, water hardness, HI, Ca, SiO. As an example, following procedures were done for analysis of Chlorine content:

1. Choose the numbers for chlorine program. Number of 80 is selected for Chloride analysis program.
2. Fill the sample cell with 25 mL of sample solution as a blank.
3. For the another sample cell, fill the sample cell with 25 mL of sample solution, then add a DPD total chlorine powder pillow.
4. Shake that solutions until the solution colour changes from clear to pink, wait for 3 minutes.
5. Put the blank into the cell holder and close the holder.
6. Press the ZERO button and wait for some minutes the display showing 0 mg / L Cl2.
7. After 0 mg / L is displayed then remove the blank sample from the cell holder and replace with a cell solution trailer.
8. Press the READ / ENTER button for the machine to calculate the chloride content in the solution.
9. Data is recorded as measurement results.

Similar procedures have been done for the measurement of other trace elements such as Fe, SO_4^{2-}, Silica HR, P reactive, water hardness, HI, Ca, and SiO_2. Each of those elements were prepared in different existing reagens for the trace elements analysis.

Corrosion rate analysis with carbon steel speciment

1. Create sample for corrosion test by making from carbon steel materials a cylindrical shape with a diameter of 1.6 cm.
2. Prepare the sample in accordance with ASTM procedures (ASTM Standard, G1-03: Standard Practice for Preparing, Cleaning and Evaluating Corrosion Test Speciments).
3. Prepare the solution test from the RSG GAS secondary cooling water and raw water.
4. Use the potentiostat to analyse the corrosion rate.

RESULTS AND DISCUSSION

The results of water quality monitoring in the secondary cooling water and in the raw water are shown in Table 1 below. It shows the pH, conductivity, Fe element, SO_4^{2-} kation, Silica HR, P reactive, Cl-, water hardness, HI, Ca, SiO_2, and corrosion rate.

Table.1. The comparison between the quality of raw water and secondary coolant water quality

No.	Chemistry parameter	Raw Water Quality			Secondary Coolant Quality		
		Standard	Test Result		Standard	Test Result	
1	pH	7-7.5	7.10	7.12	6.5-8	7.89	7.96
2	Conductivity (µS/cm)	150	148	146	950	918	920
3	Fe (ppm)	1	0.04	0.038	1	0.06	0.07
4	$SO4^{2-}$ (ppm)	67.8	14	16	320	305	310
5	Silica HR (ppm)	-	22.9	23	-	103.9	104
6	P reactive (ppm)	-	0.07	0.075	-	0.13	0.14
7	Cl- (ppm)	7.1	**9**	**9.2**	175.5	115	117
8	Hardness Total (ppm)	40	40	42	480	259	261
9	HI (ppm)	-	41	40	-	260	260
10	Ca (ppm)	34	32	34	280	184	186
11	SiO_2 (ppm)	-	24.1	24	-	102.9	103
12	Corrossion rate (mpy)		0.34	0.39	3	0.16	0.21

From Table 1. we can see that the pH in the raw water and the secondary cooling water is still within authorized limits or in the range of 7-8. Similarly in the conductivity. the conductivity value in the raw water and the secondary cooling water is still below the required standard value of RSG-GAS requirement. It can be said that the water management of the secondary cooling system and the raw water is still in accordance with the procedure. Beside of pH and conductivity monitoring. the analysis carried out on dissolved ions include iron (Fe) levels in the water. The standard for the iron content in the raw water and RSG GAS secondary cooling system is 1 ppm. while the analysis shows smaller values than the established standard.

In an aqueous solution with a pH of 7, a dissolved oxygen level is sufficient. So. the ferrous ions (Fe^{2+}), which is soluble, is oxidized into a ferritic ion. In this oxidation process, electrons are released. Therefore, at pH between 7.5 to 7.7, ferritic ions will be oxidized and bound into a hydroxide to shape $Fe(OH)^3$, which is insoluble in water and will settle to the bottom surface. In the water, the iron will bind anion Cl^- and SO_4^{2-}. From the analysis of chloride and sulphate, their contents in the RSG-GAS secondary cooling water were higher than in the raw water. That is due to the addition of inhibitors and non-bioxide in the secondary cooling water containing NaOCl as active compound. This compound is useful to kill bacterias and to control the growth of moss. However. this addition of chemicals causes a new problem from the existence of cloride content, that can lead to corrosion especially pitting corrosion in the pipeline on secondary cooling system, even the addition of inhibitors and non-bioxide will decrease the water pH level. Therefore, to fulfill the degree of acidity in the secondary cooling water, the pH value of 7 – 8 should be maintained by adding H_2SO_4. The H_2SO_4 is the secondary cooling system can prevent the formation of calcium salts, divalent metal salts and phosphate salts. The solubility of the material forming the crust will increase at a lower pH, while the pH values effectively preventing the formation of the crust are only at 7.0 to 7.5. Therefore, addition of sulfuric acid by injection process in the secondary cooling system is required in order to keep that pH value to be stabilized at 7.

Water hardness due to the content of metal ions, especially divalent ions such as Ca. Mg. Fe. Mn are also shown in Table 1. These cations will react with anions in the water to form salts which then will stick on system component. Some anions existing in the secondary cooling system are HCO^{3-}, SO_4^{2-}, Cl, and SiO_2. From the analysis, the total hardness in the raw water had an average value of 41 ppm, which is still below the required standard of 40 ppm. At the secondary cooling water, the hardness value is 260 ppm, which is also within in the tolerance limits. Based on the hardness value classification listed in Table 2 [12], the hardness value on the secondary cooling water belongs to the hard value classification (150-300 ppm).

Table 2. Hard value classification of water

Water hardness (ppm $CaCO_3$)	Hard value classification of water
< 50	Soft
50 – 150	Moderately hard
– 300	Hard
>300	Very hard

From the result analysis of calcium in the water, the calcium content was below the limit required by RSG-GAS document. The crust from the calcium built up will not be found, if demineralized water is used due to the absence of dissolved salt. Therefore, the use of demineralized water is an appropriate method to inhibite the forming of crust in a system. It is an effective way and more friendly for the environment because no chemicals addition is needed.

The result of the corrosion rate of carbon steel material in the secondary cooling water as a solution shows the value of 0.34 mpy, while the corrosion rate of raw water solution is 0.16 mpy. From that corrosion rate analysis, it can be concluded that inhibitor can inhibit the corrosion process showed by a decrease of corrosion rate after the addition of inhibitors.

CONCLUSION

Based on the water chemistry analysis on the RSG-GAS secondary cooling system, it can be concluded that the water chemistry management in the system has been well performed so far. All trace elements, which were measured, were still in accordance with the standard required by the RSG-GAS water chemistry requirements. Therefore, the safety of the RSG-GAS in the secondary coo-ling system can be maintained in term of the water chemistry.

REFERENCES

1. DIYAH ERLINA LESTARI dkk, " Pengaruh Bioksida Pengoksidasi Terhadap Petumbuhan Mikroorganisme Pada Air Pendingin Sekunder RSG-GAS", Prosiding Nasional V SDM Teknologi Nuklir-ISSN 1978-0176, Yogyakarta, 2009.
2. DHIMAN CHAKRABORTY et al, "Disinfection of Water in a Batch Reactor Using Chloridized Silver Surfaces", Elsevier: Journal of Water Process Engineering Vol.16 pp: 41-49, 2016.
3. VEERA GNANESWAR GUDE, "Review Wastewater Treatment in Microbial Fuel Cells-an Overview", Elsevier: Journal of Cleaner Production. Vol 122. 20, pp: 287-307, 2016.
4. FABRIANA MESTRINELLI, "Isolation and Caracterization of a Microorganism Involved In Sulfide-Oxidizing Autotrophic Denitrification In a Vertical Fixed-Bed Reactor". Elsevier: Journal of Water Process Engineering, Vol 11, pp: 138-142, 2016.
5. DWI SUHARTANTI, "Laju Korosi Baja Oleh Desulfomicrobium Baculatum dan Desulfomonas Pigra", Jurnal Berkala MIPA, Vol 16(1), Universitas Ahmad Dahlan, Yogyakarta, 2006.

6. I.B. BEECH et al, "Biofilm and Biocorrosion", ScienceDirect: Understanding Biocorrosion, pp:33-56, 2014.
7. DIYAH ERLINA LESTARI dkk, "Pemantauan Kandungan Ortofosfat Sebagai Parameter Uji Pengoperasian Sistem Injeksi Inhibitor Korosi (PAQ 2) Pada Sistem Pendingin Sekunder RSG-GAS". Prosiding SDM Teknologi Nuklir-ISSN 1978-0176, Yogyakarta, 2010.
8. MD MAYEEDUL ISLAM, "Condensation Corrosion of Carbon Steel at Low to Moderate Surface Temperature and Iron Carbonate Precipitation Kinetics", Elsevier: Corrosion Science, Vol. 111, pp: 139-150, 2016.
9. QINGLI CHENG, "Corrosion Behaviour of Q235B Carbon Steel In Sediment Water From Crude Oil", Elsevier: Corrosion Science, Vol. 111, pp: 61-71, 2016.
10. ANONIMOUS, "Safety Analysis Report Rev 8 Multipurpose Reactor G.A Siwabessy, Volume 3, 1999.
11. ROBERT L. SINDELAR, "Water Quality and Corrosion: Considerations for Nuclear Reactor Systems", Journal of The South Carolina Academy of Science, Vol. 9: Iss.1. Article.13, 2011.
12. N. O. A. NASSER. A. A. M. ALI, "Hardness Removal From Drinking Water", Journal of Engineering, Vol/ No: 12 (2), 2006.